Analyzing relationship between ERP utilization and lean manufacturing maturity of Turkish SMEs

Cagatay Iris
Department of Transport, Technical University of Denmark, Copenhagen, Denmark and Department of Industrial Engineering, Istanbul Technical University, Istanbul, Turkey, and
Ufuk Cebeci
Department of Industrial Engineering, Istanbul Technical University, Istanbul, Turkey

Abstract
Purpose – The purpose of this paper is to understand how effective Turkish small and medium size enterprises (SMEs) use enterprise resource planning (ERP) systems in module aspect and to assess the adherence to lean manufacturing requirements. Obtaining each efficiency result separately is not adequate to make an inference about relationship between ERP and lean practices. Hence, a relational model is developed to analyze correlation between use of ERP and lean manufacturing implementation in white goods manufacturing SMEs of Istanbul, Turkey.
Design/methodology/approach – The examination of the proposed conceptual framework is made by statistical analyses. In parallel, leveling efficiency of each enterprise requires an expert analysis in order to obtain a fair comparison. Hence, authors have visited each facility to evaluate performance of ERP efficiency and lean manufacturing applications. In Istanbul region, 53 of total listed SMEs are visited. The questionnaire survey is designed by considering different scales of performance. Exploratory factor analyses and various correlation analyses are applied to figure out relationship between ERP use and lean manufacturing.
Findings – Interaction with rapid development of information technology (IT) and progress in modern production management strategies have emerged. Obtained results show that Turkish SMEs have widely initiated lean production practices. However, applications are in initial level in the most cases. In respect to ERP systems, enterprises are more active, some basic modules are extensively used. Another finding of this study implies that effective usage of specific ERP modules can contribute toward applying lean principles, vice versa.
Research limitations/implications – The whole sample space of white goods SMEs could not be covered due to the fact that, each facility is visited and field studies are done. However, sample size calculations prove that attained feedback is statistically significant (adequate) to reflect sample space.
Originality/value – The literature studies reveal that there is an obvious lack of studies which focus on relationship between ERP use and lean manufacturing. Finding such a correlation helps IT-practitioners to design ERP modules by assessing related requirements of lean philosophy.
Keywords Enterprise resource planning (ERP), SMEs, Factor analysis, Correlation, Lean production
Paper type Research paper

1. Introduction
Nowadays, companies are continuously looking for ways to improve their performance and stay competitive in their markets. The impact of global competition forced all of the contributing partners in the supply chain to optimize its own areas of interest. In this respect, enterprise resource planning (ERP) and lean production applications
are important not only for big companies but also for small and medium size enterprises (SMEs) to cope with competitors and to add value to supply chain involved. The latest reports released by Turkish Statistical Body (TUIK) reveal that 65 percent of overall production and 85 percent of employment deployed in Turkey are by SMEs (TUIK, 2012).

The increasing competitive nature of industry has increased the diffusion of ERP systems and lean manufacturing applications due to valuable contributions to efficiency of enterprises. The prior principle lying under both tools is to create efficient ways to facilitate business activities. ERP systems which are based on information technology (IT) focus on integrating different business functions and departments in an efficient manner. While, lean production which has proven itself successfully with different practices, aims to keep the value-added activities in the process while eliminating all wastes and non-value added operations. In the initial phases of implementation, ERP systems are considered as the bottlenecks in applying lean production approaches (Halgeri et al., 2008). Such a misconception may result in systems where ERP use and connection with shop-floor operations are not integrating. Additionally, lean spreads beyond the relatively stable manufacturing environment which originally was designed to support (Riezebos et al., 2009).

In order to determine the efficiency of system, researchers should measure the utilization of ERP system and the gain obtained via lean tools. Using ERP systems does not directly mean that they are commonly accepted and utilized by users in the enterprise. Therefore, understanding how effective SMEs use such tools has a vital role to improve the related business functions and consequently overall system performance. However, measuring and scaling these parameters are mostly based on perceived outcomes. To overcome such a problem, researchers need to consider utilization in terms of common master data, degree of integration of business processes, utilization of the broad functionality, and to what extend potential users use the system.

Lean production is another fundamental strategy (apart from ERP use) which aims to conduct business activities with value-added aspects. It is considered that the measurement of lean maturity will be of enormous help to enterprises embarking upon their roadmap by distinguishing the possible focus of concentration. Areas which are described with strong applications may be improved, and the ones which lack application may be initialized. Equally, lean maturity findings along with ERP utilization may give new insights to analyze both tools together.

The aim of this study is to analyze the maturity levels of Turkish SMEs on ERP systems and adherence to lean manufacturing applications. Models that focus on both distinct areas (ERP and lean manufacturing) have not analyzed relationship levels in a combined aspect. The prior goal is to quantify ERP usage and its utilization in module aspect and then test each lean approach tool application with regular visits to enterprises. The study also proposes a relational model that formulates an empirical relationship between usage of ERP systems and lean production implementations in white goods SMEs of Turkey. By having a reasonable correlation between ERP modules and lean tools associated, both companies and ERP software developers may concentrate on pre-defined development areas. Since, there are some studies about different sectors (Sezen et al., 2012), white goods SMEs are selected as pilot application.

The organization of the paper is as follows. In the second section, a wide-scale literature review will be conducted, and lack of study aspects will be revealed. After describing the requirements, methodological structure of paper is presented,
parameters regarding ERP utilization and lean maturity will be clarified. Related result of the survey will be detailed with factor analyses of each tool and correlation analysis between factors in the fourth section. Finally, conclusion and future research direction are to be noted.

2. Literature review
Focus of literature survey is decomposed into three basic research areas. As mentioned before, the first part is looking into details about analyzing performance of ERP systems, and their utilization. In this section, studies, which explore use of ERP by SMEs and measuring effectiveness of use, are presented. In second sub-section, selection of lean tools that reflects adherence to lean philosophy is initially discussed. After this, some empirical studies applied in automotive industry to determine maturity of leanness are presented. Additionally, studies which focus on survey design on lean tests are explained. In this last part, contradiction between ERP and IT is discussed. Then, effects of ERP use on different business functions such as supply chain management (SCM), business performance (BP) are analyzed. Finally, studies about ERP systems, which support lean production that are deployed and convergence of ERP systems to lean philosophy with proving relationships in between, are explained.

2.1 ERP systems and utilization
During the past decade ERP has attracted attention from both academic and industrial communities. Some extensive literature surveys which include high numbers of papers are published, and each literature survey has emphasized some lack of concentration in ERP literature (Schlichter and Kraemmergaard, 2010; Pages et al., 2010). Most of the latest reviews note that implementation of ERP systems in SMEs systems are not extensively clarified. Most of the implementation articles are best practices of ERP applications in SMEs, however, there is not detailed studies on performance evaluation of ERP usage in these companies. Esteves (2009) has described the roadmap for an effective ERP system integration in SMEs. Proposed empirical study shows that implementation phase of ERP systems should be evaluated analytically in order to clarify needs and outcomes. Another study which focusses on Belgian SMEs has explained a comparison of critical success factors in ERP implementation. It is deduced that the need to adjust their businesses quickly to be able to exploit their niche to the fullest extent is prior driver. Hence continuous analysis of infrastructure and approaches has a vital role in order to manage process in an efficient manner (Doom et al., 2010).

There are some other studies which analyze factors affecting ERP system integration in SMEs (Maditinos et al., 2012; Ramdani et al., 2009). One of these articles has proposed an examination of the conceptual framework with the use of a newly developed structured questionnaire and the results offer interesting implications to ERP adopting companies. The paper helps practitioners to measure input variables for ERP efficiency (Maditinos et al., 2012). Federici (2009) has explained some other factors influencing ERP outcomes of SMEs. And, it is found out that one of the most influential factors is attaining valuable business activities. In this respect, it is vital to evaluate maturity level of ERP usage. Buonanno et al. (2005) have explored the use of ERP by SMEs and tested numerous hypotheses. In this study, performance evaluation in respect to ERP application is done according to modules’ usage efficiency in a quantitative way. The precision with the members of the ERP analysis teams could
provide an evaluation which is limited by their knowledge, experience, and even cognitive biases, as well as by the complexity of the ERP system execution. Hence, evaluating utilization of ERP systems analytically have also embarked the attraction of many researchers (Wei, 2008; Hedman and Johansson, 2009). Some studies are based on fuzzy linguistic results of the ERP examination of the users involved (Chen and Lin, 2009). Due to fact that different users may have imprecise attitudes toward the tool, fuzzy techniques may work quite efficiently. In this study, we have tried to quantify ERP utilization with three basic aspects that may help to obtain output variables. Factor analysis is utilized to create the shortened list of such variables (Amid et al., 2012; Botta-Genoulaz and Millet, 2005).

2.2 Lean production maturity measurement
Since scope and significance of lean thinking is evolving over time with new challenges in the industry, studies that cover literature becomes more detailed and popular. In such articles, authors intend to determine key parameters and tools of lean philosophy so that a comprehensive way of understanding may be established. Lean studies mostly cover the operational best practices of lean techniques with such pre-determined tools (Sezen et al., 2012; Satoglu and Durmusoglu, 2003).

In this paper, empirical studies will be mostly presented in order to assess lean maturity levels of white goods SMEs. Shah and Ward (2007) have defined parameters that can be used to test lean production activities. The aspects are limited to ten fundamental requirements used in internal, external, and value chain lean philosophy activities. These aspects are tested statistically and results show that lean production is conceptually multifaceted, and its definition spans philosophical characteristics that are often difficult to measure directly. Furthermore, the practices/tools used to measure lean production, even when associated uniquely with a single component, indicate mutual support for multiple components (Shah and Ward, 2007). Another study which concentrate on Turkish automotive industry with a high sample size, has proposed a similar methodology. In this study, Sezen et al. (2012) have listed basic maturity assessment tools as setup time reduction, pull production, small lot sizes, inventory reduction, one piece flow, value stream mapping, process improvement, preventive maintenance, cellular manufacturing, 5S, cleanness, root-cause analysis, kaizen, poke-yoke, waste elimination, etc. According to factor analysis results, it is deduced that the list of the tools represents a remarkable percentage of lean applications. Some other studies have been proposed in order to determine maturity and capability of enterprises in lean production. And, it is stated that the aspects that trigger or catalyze adoption and the measurement of capability are not extensively clarified (Moyano-Fuentes and Sacristán-Díaz, 2012). Finally, most of empirical studies state that measure of alignment to lean philosophy is mostly presented with Likert scale (Sezen et al., 2012; Furlan et al., 2011).

2.3 Correlation between ERP utilization and lean maturity
Most of the studies in literature focus on ERP and lean in separate focusses. Schlichter and Kraemmergaard (2010) have published a literature survey on ERP studies and emphasized that affect of ERP usage on other business activities of facilities are not analyzed in detail. However, Yang and Su (2009) have established a relational model that reflects relationship between ERP and SCM performance. The methodology used in study is based on canonical correlation which aims to build a correlation between
multivariate parameters. Other studies which reflect ERP usage and relevant areas consider ERP with operational performance (OP) and financial performance (Madapusi and D’Souza, 2012; Liu et al., 2007; Pagès et al., 2010).

Riezebos et al. (2009) have focussed whether there is a connection or contradiction between ERP usage and lean production. It is emphasized that ERP software mostly lack supporting lean production activities in aspects. According to the authors, the strong application findings may be grouped into three basic ERP modules; maintenance, production planning and control, and computer-aided production. Another study that proposes ERP enabled KANBAN system, has been prepared as a best practice with real-time roots in industrial application (Steger-Jensen and Hvolby, 2008). In this study, ERP module is configured with requirements of pull-based system. Some other implementations that consider Just-in-time (JIT) practices, and lean production planning is also presented (Ward and Zhou, 2006; Moyano-Fuentes et al., 2012). Finally, a literature survey is published that focus on ERP systems that support lean production. In this study, examples of lean process mapping tools, JIT applications, KANBAN, demand smoothing, value-stream mapping have been detailed (Halgeri et al., 2008). However, the studies that focus on statistical correlation between these tools have not extensively attracted researchers.

3. Methodology
3.1 Establishment of research model
The empirical objective of this study is to identify the dimensional structure underlying lean production applications and ERP utilization and to develop reliable and valid scales to represent relationship between these tools. We adopt a comprehensive multi-stage approach which starts with the sample size validity analysis, after that a questionnaire was constructed based on an extensive review of the literature in the areas of ERP and lean production implementation. By using results obtained from surveys detailed factor analyses are applied for each tool. Obtained factors are interpreted with convergences to cases in real production life. After having listed each factor, an extensive statistical analysis is applied to understand correlation between these factors.

3.1.1 Instrument development and measurement. In the phase of instrument development, previous literature is utilized to obtain insights into measurement. To minimize expected variability and measurement errors pre-tested scaling systems are adapted (Shah and Ward, 2007). In order to reflect overall characteristic of lean philosophy, proposed test parameters are validated with practitioners who are continuously dealing with such problems. Final test plan is presented in Table IV header. Maturity of ERP use for each of 14 modules is determined by using two main parameters. It is a combined version of the effective usage of modules (E1: percentage of tasks done by using ERP) and efficient usage of modules (E2: correctly usage of ERP modules). Hence, overall utilization of ERP module is a non-metric parameter to be used in statistical inferences (Overall = E1 × E2). As it is mentioned, each ERP module is tested with strategy proposed in (Federici, 2009). In parallel, lean production is tested by considering six fundamental aspects; 5S, single minute die exchange (SMED), pull-based production (KANBAN), total preemptive maintenance, cellular manufacturing, quality assurance and management. Each of listed frames has sub-questions to understand actual level of lean production maturity. The data gathering questions are qualified with a five-point Likert scale which reflects perceived performances. After defining pilot test instruments with ten different experts working
on ERP systems and lean manufacturing, questionnaire is revised regarding self-testing of adapted parameters with easy-to-rate performance measures. Selection of ideal respondents is made by using jobs-description matrices which is prepared by human resource departments.

3.1.2 Sampling. Since the study is applied to Turkish White-Goods SMEs located in Istanbul region, first the candidate enterprises were determined to participate. One manager of each enterprise who was responsible for implementing ERP was visited, and authors rate the level of the success in achieving improvements and lean production maturity. Related list of all alternative companies is obtained from Istanbul Chamber of Commerce. In 2011, overall alternative space which is sample domain contains 148 different enterprises. Obtained 53 observations correspond to a 0.35 efficient response rate. Calculation of minimum sample size could be done by using Equation (1) shows statistical significance:

\[
n = \frac{N \cdot t^2 \cdot p \cdot q}{d^2 \cdot (N - 1) + t^2 \cdot p \cdot q}
\]

where, \(N\) is the sample domain = 148 (2011); \(t\) is the Std. normal distribution coefficient = 1.96 (95 percent); \(p\) is the observation frequency (probability) = 0.5; \(q\) is the non-observation frequency = 0.5; \(d\) is the sensitivity = 10 percent; \(n\) is the representing minimum sample size (≥52): statistically adequate.

3.1.3 Data gathering. Direct interviews and factory visits are made to collect information from the engineers and IT professionals/manager in every company. Although interviewer-administered surveys are expensive and time consuming, it was preferred because it allowed us to gain a fairly good quality of response. Additionally, self measuring the rate of lean practices, and ERP usage is hard for companies, because the questions about ERP usage and lean are of a contemporary nature. This technique was useful because it enabled the interviewer to correct any ambiguities and unfold any issues raised by respondents (Ramdani et al., 2009). It should be noted that obtaining good response rates are crucial for statistical analysis. By applying field study and direct interviews, quality of responses has increased, and requirements for early/late response analysis have disappeared.

3.2 Exploratory analysis and data reduction

In order to state characteristics more precisely, descriptive statistics regarding open-ended questions and missing item analysis were conducted for each of both ERP and lean parameters. The results did not indicate any problems with the missing item analysis. Second, an item to total correlation (ITC) score was calculated for each lean item to assess item reliability. Since, not a Likert scale but the percentages are assigned for ERP modules, ITC calculation is not required. Results, which are shown in Table IV with “ITC” row, are used to drop the questions which are not strong enough to reflect characteristics of research model. The rule of strength is set with parameter higher than 0.30 (Shah and Ward, 2007). After this, descriptive statistics of enterprise pool is presented in Table I.

Table I shows the distribution of 53 companies in three separate categories, namely, “company size,” “customer group,” and “financial indicators.” In total, 92 percent of the companies in the sample operate as the first tier suppliers in the white goods industry based on the main product they offer to the market. Regarding the fact that 48 of all enterprises are owned by Turkish capital, enterprises may be
attributed as local SMEs. The sizes of enterprises are measured by the number of employees, age of company, and the number of customers. Although, there are a number of micro enterprises which have relatively low numbers of employees and customers, the average values of parameters reflect that sample has mostly medium size companies. When companies included in the survey are classified according to their size based on the number of employees, it is revealed that the representations of large-, medium- and small-size companies are comparable (Sezen et al., 2012).

The research model finally requires a framework to show basic steps of the analysis. With the information gathered by company profiles, further analysis may be conducted. Initially, the data are analyzed by means of 14 ERP modules and descriptive parameters are obtained for each module (mean usage, standard deviation). The same procedure is also applied for lean manufacturing assessment. After determining overall means, exploratory factor analysis is applied to understand actual characteristics of modules and lean production application. Finally, correlation analysis is made to understand relationship between each factor, and results are explained in respect to ERP software improvement phase and lean production application capability. Figure 1 represents general flow of information gathering and component of survey which is applied by authors to enterprises.

### 4. Survey results

The conceptual framework of the present study suggests that ERP modules have factors that may describe overall system utilization in the best manner. Additionally, it is also noted that lean production requirements have their own levels, and listing them as a whole is not enough to reflect core effects of lean implementation. Finally, interaction between specific ERP modules and lean application parameters are up to analysis, if ERP packages that supports lean are investigated. For these conceptual requirements, survey results are clustered not according to the analysis type, but considering analyzed factors.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Categories</th>
<th>Frequency</th>
<th>Mean (M)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of employees</td>
<td>0-50</td>
<td>23</td>
<td>140.12</td>
<td>202.06</td>
</tr>
<tr>
<td></td>
<td>50-150</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>150-250</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enterprise ownership</td>
<td>Local</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of enterprises</td>
<td>0-10</td>
<td>3</td>
<td>26.4</td>
<td>12.22</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;30</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of customers</td>
<td>0-50</td>
<td>27</td>
<td>38.14</td>
<td>18.14</td>
</tr>
<tr>
<td></td>
<td>50-100</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100-150</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;150</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual revenue (million $)</td>
<td>0-5</td>
<td>21</td>
<td>14.52</td>
<td>15.44</td>
</tr>
<tr>
<td></td>
<td>5-15</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-50</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;50</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table I. Descriptive statistics of enterprise profiles
4.1 ERP utilization results

In order to evaluate the extent of ERP performance of Turkish white good suppliers (SMEs), the mean values of responses to the questions in the ERP modules are examined (e.g. Hedman and Johansson, 2009; DeLone and McLean, 1992). The calculated mean values for the questionnaire items in Table II show that the ERP utilization levels differ with respect to modules of ERP system. Basic ERP modules which are listed here are coded for ease-of use as: purchasing (PR), bill-of-material (BOM), production management and scheduling (PM), inventory management (IM), sales (SL), customer relationship management (CRM), finance (FN), accounting (AC), master planning (PL), quality management (QR), human resource management (HR), budgeting (BT), data automation (DA), maintenance management (MM).

Table II reflects that Bill-of-Material and accounting modules are most commonly used, while CRM and automated data gathering systems are not widely utilized. Since the most utilized modules are basic initialization modules, the rest of information architecture is built upon them. It is also deduced that relatively new modules such as CRM, data automation, real-time information sharing with shop-floor, and maintenance management modules are not commonly used. However, enterprises that initiate these modules use them in a more effective way.

Although, modules such as purchasing, inventory management, finance have relatively high utilization. Enterprises lack further performance by applying all tasks by these modules such as ABC analysis, continuous supplier evaluation plans, contract management, on-order inventory planning, available-to-promise analysis, purchasing lot sizing and optimization, financial scenario management, capacity planning, scheduling, inter-depot transfer, etc. tools of ERP systems. It is also required to consider the standard deviation of results of each module. It is observed that there is a huge fluctuation in usage of human resources and data automation between enterprises.

There are also some modules which are used in average. These modules may be clustered as; quality management, sales, human resource management. These business
Table II. Descriptive statistics for ERP module usage

<table>
<thead>
<tr>
<th></th>
<th>PR</th>
<th>BOM</th>
<th>PM</th>
<th>IM</th>
<th>SL</th>
<th>CRM</th>
<th>FN</th>
<th>AC</th>
<th>PL</th>
<th>QM</th>
<th>HR</th>
<th>BT</th>
<th>DA</th>
<th>MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usage</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
<td>E2</td>
<td>E1</td>
<td>E2</td>
</tr>
<tr>
<td>Mean</td>
<td>0.81</td>
<td>0.79</td>
<td>0.90</td>
<td>0.82</td>
<td>0.76</td>
<td>0.85</td>
<td>0.83</td>
<td>0.71</td>
<td>0.72</td>
<td>0.46</td>
<td>0.41</td>
<td>0.81</td>
<td>0.82</td>
<td>0.96</td>
</tr>
<tr>
<td>SD</td>
<td>0.18</td>
<td>0.22</td>
<td>0.08</td>
<td>0.15</td>
<td>0.19</td>
<td>0.13</td>
<td>0.14</td>
<td>0.26</td>
<td>0.25</td>
<td>0.29</td>
<td>0.29</td>
<td>0.18</td>
<td>0.10</td>
<td>0.08</td>
</tr>
<tr>
<td>Overall</td>
<td>0.64</td>
<td>0.86</td>
<td>0.63</td>
<td>0.71</td>
<td>0.51</td>
<td>0.19</td>
<td>0.65</td>
<td>0.91</td>
<td>0.52</td>
<td>0.37</td>
<td>0.34</td>
<td>0.73</td>
<td>0.08</td>
<td>0.15</td>
</tr>
</tbody>
</table>
functions correspond to basic support activities. Although, main frames of each module are applied (quality control, inspection, sales order, employee data records), extended analysis aspects are neglected.

It is found out that most of the SMEs use basic modules, but they do not efficiently utilize the report and analysis capabilities of ERP software.

To assess divergent validity, the 14 items that were retained were subjected to an exploratory factor analysis. Phases of factor analysis are diversified by similar literature studies (Amid et al., 2012). Factor analysis is conducted on explanatory variables, with the objective of determining minimum number of factors representing maximum variance of data obtained in ERP module usage results. For related data set, Kaiser-Meier Olkin test statistics is obtained as 0.61 which corresponds to an applicable set with Bartlett's test significance zero. Overall statistics show that data set is applicable for factor analysis. Varimax rotation is used with principle component analysis. Factors having an eigenvalue > 1 are selected to be presented in the factors list. For rotated component matrix, there are five different factors with item-loadings which are illustrated in Table III. These factors explain 84.32 percent of overall variance.

According to rotated component matrix; F1 (including; QM, MM, HR dominantly) represents overall equipment efficiency (OEE) parameters which all together corresponds efficiency of manufacturing systems. F2 (including; CRM, DA dominantly) corresponds to new technologies adapted to ERP systems recently. While F3 (including; PR, AC, BT) directly represents purchasing based accounting and budgeting activities. F4 (including; BOM, IM, PM, PL) corresponds to production planning and control activities. Finally, F5 (including; SL, FN, BT) gives direct information on sales and finance activities. Factor derived from survey is very sensible in respect to usage comments that are made in previous sections. Factors obtained in this phase will be used in further analysis.

After defining each factor which combines rational subgroups to reflect different characteristics of ERP module utilizations, further analysis may be applied to understand drivers of ERP usage in SMEs. Data regarding ERP implementation period (for how long) may also have an impact on ERP utilization. Average factor utilization is used in this sense. The obtained results denote that the higher implementation period has the enterprises, ERP utilization gets higher. However, this correlation is comparatively low between F2 and ERP implementation length.

Empirical results of this phase should also be compared with other studies in order to come up with implacable solution strategies. Compared with Botta-Genoulaz and Millet (2005) which present a synthesis of three recent French surveys, Turkish SMEs perform very similarly in a number of modules. In this study, average usages are distributed between 75-90 percent for main modules, and to a lesser extend support modules have implementation frequency around 30-50 percent (Botta-Genoulaz and Millet, 2005).

In the next phase, similar analyses will be conducted to lean production maturity tests. However, clustering of lean application techniques will not be done, because each technique will be presented under a pre-defined topic in literature (Sezen et al., 2012).

4.2 Lean production maturity results
In this phase, we have performed a field study to measure lean production maturity of listed enterprises. Initially, descriptive statistics of each lean philosophy component are presented. The relevant comments on how to improve these areas may be considered as
<table>
<thead>
<tr>
<th>Factors</th>
<th>Purchasing (PR)</th>
<th>Bill-of-material (BOM)</th>
<th>Production management (PM)</th>
<th>Inventory management (IM)</th>
<th>Sales (SL)</th>
<th>Customer relations management (CRM)</th>
<th>Finance (FN)</th>
<th>Accounting (AC)</th>
<th>Planning (PL)</th>
<th>Quality management (QM)</th>
<th>Human resources (HR)</th>
<th>Budgeting (BT)</th>
<th>Data automat management (DA)</th>
<th>Maintenance management (MM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>0.28</td>
<td>0.48</td>
<td>0.29</td>
<td></td>
<td></td>
<td>0.33</td>
<td>0.36</td>
<td>0.82</td>
<td>0.67</td>
<td>0.83</td>
<td></td>
<td>0.89</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>0.44</td>
<td></td>
<td>0.88</td>
<td>0.25</td>
<td></td>
<td>0.52</td>
<td></td>
<td>0.36</td>
<td>0.25</td>
<td>0.76</td>
<td>0.89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.74</td>
<td>0.61</td>
<td></td>
<td>0.42</td>
<td>0.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F4</td>
<td>0.80</td>
<td>0.58</td>
<td>0.81</td>
<td>0.31</td>
<td></td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.81</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table III. Rotated component matrix

ERP utilization and lean manufacturing
a system analysis phase for designing ERP modules. In this study, relationship between ERP and lean manufacturing is determined as a direction-free arc. The basic tools of lean production that are assessed are; 5S applications, pull-production systems, total productive maintenance (TPM), SMED, cellular manufacturing, and quality assurance and management.

The survey questions are designed in such a way that starting from the first question, implementation performance gets higher with the increasing number of questions. The initial questions of each phase correspond to initial implementations in shop-floor.

Obtained results (Table IV) show that adherence to value-addition principle of lean production is not in satisfactory level. The first aspect that takes the attention is KANBAN-based pull-production strategy is the main problem in the most of facilities. It seems that facilities mostly apply lean instruments in initial phases. Further steps which require analytical projects are mostly neglected. Easy-to-implement strategies are very common among facilities, but further analysis mostly lacks. In sub-sections of pull-production, TPM, SMED, and cellular manufacturing, points are dramatically getting lower with the further questions. In 5S (7S), enterprises show an average performance. Most of them believe that they perform well, however the continuity of implementation and tools of 5S are not commonly internalized by workers. Similarly, TPM policy and goals are set by most of SMEs but implementations starting from OEE calculation with autonomous maintenance scheduling are not performed widely. It is deduced from analysis phase that activities which are directly linked to production activities are not optimized. Cellular manufacturing which may be linked to production planning phase in ERP systems is locally implemented in shop-floor. Parameters of quality assurance and management have low marks; however, standard deviations of these parameters are relevantly high.

The questions about each subtitle are inspired by a lean capability model which emphasize lean understanding, optimization, lean interventions, and proactive lean culture (Jorgensen et al., 2007).

According to obtained results, there should be six factors which are direct representatives of main frames that we have proposed in this study. Hence, means are calculated for each type of lean production aspect and these values are used in correlation analysis. After this phase, correlation between ERP usage and lean maturity may be analyzed.

4.3 Canonical correlation analysis
One of the prior aims of this study is to identify how strong is the interaction between efficient implementation of ERP and implied lean production performance. In order to summarize this relationship, canonical correlation analysis is conducted using both the ERP data and the matching lean production maturity data described in previous section. Canonical correlation analysis is a way of making sense of cross-covariance matrices. If we have two sets of variables, \( x_1, \ldots, x_n \) and \( y_1, \ldots, y_m \), and there are correlations among the variables, then canonical correlation analysis will enable us to nd linear combinations of the \( x \)'s and the \( y \)'s which have maximum correlation with each other (Sohn and Lee, 2012). Canonical correlation is appropriate in the same situations where multiple regression would be, but where are there are multiple intercorrelated outcome variables. Canonical correlation analysis determines a set of canonical variates, orthogonal linear combinations of the variables within each set that best explain the variability both within and between sets. The output analysis begins
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>2.6</td>
<td>2.5</td>
<td>2.5</td>
<td>2.4</td>
<td>2.9</td>
<td>2.9</td>
<td>2.8</td>
<td>2.7</td>
<td>1.6</td>
<td>1.4</td>
<td>2.2</td>
<td>2.1</td>
<td>2.8</td>
<td>2.6</td>
<td>3.3</td>
<td>2.1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
<td>1.3</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
<td>1.0</td>
<td>1.1</td>
<td>1.3</td>
<td>1.3</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>5S (7S) applications</td>
<td>Pull production</td>
<td>TPM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>itc</td>
<td>0.70</td>
<td>0.64</td>
<td>0.58</td>
<td>0.61</td>
<td>0.62</td>
<td>0.75</td>
<td>0.61</td>
<td>0.66</td>
<td>0.53</td>
<td>0.67</td>
<td>0.64</td>
<td>0.65</td>
<td>0.80</td>
<td>0.71</td>
<td>0.51</td>
<td>0.60</td>
<td>0.72</td>
<td>0.66</td>
</tr>
<tr>
<td>SMED</td>
<td>0.68</td>
<td>0.76</td>
<td>0.72</td>
<td>0.64</td>
<td>0.70</td>
<td>0.64</td>
<td>0.64</td>
<td>0.55</td>
<td>0.60</td>
<td>0.63</td>
<td>0.77</td>
<td>0.60</td>
<td>0.58</td>
<td>0.69</td>
<td>0.67</td>
<td>0.75</td>
<td>0.77</td>
<td>0.74</td>
</tr>
<tr>
<td>Setup clustering</td>
<td>SMED plans</td>
<td>Effic. implementation</td>
<td>Part and product lists</td>
<td>Part – machine matrices</td>
<td>Production cells</td>
<td>Visual inventory man</td>
<td>Pareto and fishbone diag</td>
<td>ANOVA tests</td>
<td>Value stream mapping</td>
<td>Kaizen activities</td>
<td>Hoshin kanri</td>
<td>Heijunka</td>
<td>Shojinka</td>
<td>Poke – Yoke</td>
<td>Education and training</td>
<td>Work study and measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>2.2</td>
<td>2.0</td>
<td>2.1</td>
<td>3.6</td>
<td>3.4</td>
<td>2.8</td>
<td>2.4</td>
<td>3.3</td>
<td>1.9</td>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
<td>2.2</td>
<td>2.9</td>
<td>2.9</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>1.3</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.3</td>
<td>1.2</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
with an overall multivariate test of the entire model using two important multivariate criteria of Wilk's $\lambda$ (0.75) and Hotellings' (0.32). Obtained results show that criteria calculated give further analysis opportunities (Chang et al., 2008; Shatat and Udin, 2012).

This is followed by the five canonical correlations and the multivariate tests of each of the dimensions which are shown in Table V. These results show that the first two of the two canonical correlations are statistically significant at the 0.05 level.

We also have the canonical correlations as well how much variance of the dependent variables is explained by the dimensions. For this particular model there are five canonical dimensions of which only the first two are statistically significant. After conducting related dimensions analysis, only the first two resolved as statistically significant.

Results show that there is a strong correlation of 5S activities with F1 (which reflect maintenance), F4 (production activities), F5 (managerial issues). It is also detected that there is an obvious statistically approved correlation between F1 (quality tools) and VAR6 (quality assurance) systems. The correlations which are not statistically validated should also be clarified; SMED applications seem to be affected by the most of modules used in ERP systems. Pull-based production strategies are mostly affected by F4 and F5 which are production dependent factors. Finally, obtained results of VAR4 (TPM) activities are mostly affected by F1 which contains HR, MM together.

The results of two canonical correlation functions support the methodological section. The square values of canonical correlation of these functions indicate a strong relationship between ERP performance and lean production maturity. The canonical correlation analysis results show that there is enough evidence to support the existence of this relationship (Chang et al., 2008).

### Table V.

<table>
<thead>
<tr>
<th>Canonical correlation functions</th>
<th>Eigenvalue</th>
<th>Squares of canonical correlation</th>
<th>Approx. $F$</th>
<th>Significance ($p &lt; 0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.56</td>
<td>0.84</td>
<td>8.35</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>4.32</td>
<td>0.77</td>
<td>4.56</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>1.56</td>
<td>0.61</td>
<td>1.35</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>0.58</td>
<td>0.37</td>
<td>0.97</td>
<td>0.51</td>
</tr>
<tr>
<td>5</td>
<td>0.30</td>
<td>0.23</td>
<td>0.74</td>
<td>0.69</td>
</tr>
</tbody>
</table>

#### 5. Discussion and conclusion

The key aspects of this research are its sole focus on the SME segment, the ERP implementation performances on module integration, the adherence of these SMEs to lean production principles, and determining relationship between ERP module utilization and lean production.

There are numerous positive contributions of the study. It is deduced that Turkish white goods SMEs are in the growth phases of ERP implementation. Although, most of them have launched fundamental modules, usage efficiency is not relatively high. What is more, factor analysis results show that modules may be clustered in order to implement them in an effective manner. Our research suggests that a modular approach may contribute to the usefulness of the ERP system. The enterprises, which highlight production capabilities and operational excellence, may focus on the related
set of factors. The ones which seek for advanced improvements may integrate modules which are clustered as new trends and technologies.

Results also give clues for ERP software companies. In the development stage of ERP packages, developers may take into account results of analysis so as to design information architecture of each module regarding associated lean perspective. Not only the developers of ERP systems, but also the marketing experts may utilize factor clusters of ERP systems. Proposed groups may be offered as combined packages in order to take the attention of SMEs with different levels of ERP applications.

Another significant contribution is to assess lean production performances. Correlations between the lean measurement items indicate that the elements of the model are complementing each other as a whole. The proposed model for measuring adherence to lean practices can be used for evaluating the leanness level of companies. Obtained results reveal that lean manufacturing applications are mostly in initialization level in this sector. Most of the SMEs are aware of the need to become leaner, but have problems with implementation phases. This model would also serve to catalyze decision making as managers seek to match the ERP implementations to evolving lean needs. Hence, the idea of contradiction between ERP and lean has disappeared in the SMEs. Previously, they believed integration might not be unfolded. However, applications and best practices give some fruitful clues from where to start. Results are presented in different organizations to inform SMEs to act in an effective way.

Future research could focus on establishing models that propose some hypothesis to test each relationship between modules and other relevant business parameter. The model may contain factors on company size, and its tier in the supply chain. Another aspect that may be covered is to extend the analysis to other sectors. By having such an extension, a fair comparison of white goods SMEs can be made, and with the increasing size of sample size more validated empirical analyses may be unfolded. Such studies that directly try to link lean production activities to business activities and ERP modules, will finally contribute to improve overall BP.

References


**Corresponding author**

Cagatay Iris can be contacted at: cagai@transport.dtu.dk